Daylighting Impacts on Retail Sales Performance

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The purpose of this study was to see if we could demonstrate a clear relationship between the presence of daylight and sales in retail buildings.

In this study, we used a statistical technique called multivariate regression analysis, which analyses the importance and impact of many variables simultaneously. The performance data used was an 18-month gross sales average per store for a chain retailer. This analysis allowed us to estimate the effect of each of the known variables and to determine which variables have no significant effect. Using this method, we established a statistically compelling connection between skylighting and retail sales.

The implications of the results of this study extend beyond the retail sector. We believe that the conclusions may be transferable to other types of buildings, such as offices and factories, since it is really human behavior that we investigated. If daylighting motivates buyers at a retail store, it is not too large a stretch to presume that it might also motivate workers in a factory.

Background

Daylighting was a widely used method of providing light to industrial and warehouse buildings before the widespread use of fluorescent lighting. Most single-story industrial buildings built before the 1950s had rows of north-facing roof monitors which allowed ample light into the interior of these large buildings. With the advent of inexpensive fluorescent lighting and air conditioning, daylighting techniques were abandoned in favor of electric lighting.

Turning off electric lights when sufficient daylight is available can save a significant amount of lighting energy costs. Recent analysis has shown that daylighting has enormous potential to provide energy savings in single-story commercial[1] buildings, especially when it is introduced from the top of the building, termed "top-lighting" rather than from windows, termed "side-lighting".

Lighting energy savings of 30 to 80 percent from skylights combined with photo-controls have been demonstrated.[2] Because daylight introduces less heat into a building than the equivalent amount of electric light, cooling costs can also be reduced for an optimally sized system.[3] Thus, increased use of skylighting systems could potentially save a considerable amount of energy nationally.

Nationally, 40 percent of all existing commercial buildings are single-story, and 60 percent of commercial square footage is directly under a roof.[4] For new construction, it is believed that these numbers are even higher. For example, in California, it has been estimated that 90 percent of non-residential new construction square footage is single-story.[5] In contrast, the floor area potentially available for side lighting is estimated at only 25 percent of the commercial building floor area.[6]

Retail buildings tend to be a fairly straightforward application for skylighting, defined as the combined use of skylights with photo-controls to turn off unneeded electric lights. The trend is towards large, single-story retail centers, with open expanses of shelving; a building type that is well adapted to a skylighting approach. Skylighting in these buildings can save significant sums of money. For example, a skylighting system in a typical grocery store in Los Angeles has been observed to save about $10,000 per year.[7] A number of national retailers have adopted skylighting as a standard design feature of their stores in order to take advantage of these energy savings.

With the advent of more skylit stores, anecdotal stories began to surface that stores with skylighting were experiencing higher sales. Most notably, an article made it into *The Wall Street Journal* about Wal-Mart's experience with skylights in a prototype "eco" store in Lawrence, Kansas, where "sales were significantly higher" in the daylit half of the store.[8] (Wal-Mart has subsequently been installing skylighting in all new stores.) Another retailer floated reports that clothing returns decreased dramatically after installing skylights. Such anecdotal studies have been intriguing, but have not offered a measure of how large or reliable such a positive effect might be.

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1 The term "commercial" is used in this paper to indicate all buildings in the commercial sector, and specifically not residential, industrial or agricultural buildings.

2 Short term monitored data from Daylighting Initiative Case Studies. 1999. PG&E .

3 Heschong, L, and McHugh, J. 2000. Skylights: Calculating Illumination Levels and Energy Impacts. J of the IESNA. 29 (No. 1). pp. 90-100.-

4 Derived from the U.S, Energy Information Agency publication. 1995.Commercial Building Energy Consumption. (CBECs) .

5 Personal communications from PG&E and SDG&E staff.

6 Derived from the U.S. Energy Information Agency publication. 1995. Commercial Building Energy Consumption (CBECs) 1995

7 Per monitoring by PG&E for daylighting case study series, which showed savings of 2 kWh/SF per year for a 50,000 SF store paying $0.10/kWh.

8 Pierson, John. 1995. Letting the Sun Shine is Good For Business. Wall Street Journal, Nov 20, 1995

A simple analysis shows a modest increase in sales could be at least as interesting to a retail owner as potential reduction in lighting energy costs. For example, according to the Food Management Institute, average grocery store sales in the United States were $491/SF per year in 1997 and average profits $6/SF per year.[9] A 5 percent increase in sales is worth $25/ft^2 and a minimum increase of $0.30/ft^2 in profits (assuming no increase in rate of profit realized on an increase in sales). In comparison, energy use from grocery store lighting is likely to average $1.00/ft^2 per year.[10] A 30 percent reduction in lighting energy use due to skylighting would thus also be worth about $0.30/ft^2.

Study methodology

Our interest was to study the potential effect of daylighting on the performance of people in similar buildings with and without skylights. To do this, we sought organizations with pre-existing productivity measurements that could be compared between buildings with and without skylights (or daylight). We began by casting a wide net looking for the ideal organizations that could provide us with data sets amenable to our analysis.

We were looking for organizations that operated at many nearly identical sites, where about half the sites contained skylights and the other half did not, or where there was a wide range of daylight conditions that could be reduced to a relatively simple numerical scale. It was important that, other than variations in daylighting, the sites be as identical as possible. They should follow similar operations, and be in similar climates. It was also necessary that there be an on-going measure of performance for each site. We conducted a nationwide search looking for organizations that met these criteria.

We were fortunate to find a retailer and three school districts that met all of these conditions, and that were willing to participate in the study. This paper describes the findings from the retail analysis.

The retailer, who wishes to remain anonymous, operates a set of nearly identical chain stores that sell a variety of consumer merchandise. Two thirds of the stores in the study had skylights and one third did not. The retailer provided us with basic descriptive information about its stores and a "sales index" for each location. The sales index became the measure of performance for each site.

The study used multivariate linear regression analysis, a statistical analysis technique, to control for other influences on retail sales. These mathematical models allowed us to isolate the effect of one variable, while simultaneously controlling for the influence of all the others. The models also tell us the statistical probability that we have identified a valid effect, and the power of each variable in predicting results.

The retailer

The design and operation of all the stores in the chain is remarkably uniform. Other than the presence of skylights, the skylit stores have two other features that differentiate them from the non-skylit stores: higher ceilings and photosensor control of the lights under the skylights. No other systematic difference between skylit and non-skylit stores was observed. All of the stores were laid out in nearly identical fashion, so that similar items were located in similar places. Stores of the same vintage had similar signage and decoration within the stores, and similar façade design and parking layout outside. The individual stores are managed at the corporate level, so management and advertising are similar between sites. At night, without the presence of daylight, the appearance of all the stores and interior lighting levels are strikingly similar.

The decision to put skylights in a store was largely an historical circumstance. The policy of the chain was to include skylights in new stores in order to accrue energy savings. However, many new stores without skylights were added to the chain through acquisition and then remodeled to meet the design standards of the chain.

The store design of the retailer in this study would best be described as an exemplary, skylighting application. The skylights diffuse any sunlight so that there is uniform illumination below. The design provides high illumination levels during peak daylight hours, often two-to-three times the electric lighting levels. The electric lighting design throughout the stores is also carefully thought out in relation to the skylighting and is consistently applied. Most of the electric lighting is fluorescent, with strategic display lighting and highlighting used in both the skylit and non-skylit stores. Quality lighting design is clearly considered part of the merchandising strategy for the chain.

Variables considered

Stores in the sample were selected to operate within a limited geographic region that had similar climatic conditions, and to have constrained ranges of size and age. The geographic region has a relatively sunny climate. All of the stores in the data set are one story. Data were provided on 108 stores in the chain, two thirds with skylights and one third without.

The sales index provided was an arithmetic measure of gross sales per store averaged over an 18-month period. The 18-month period included two spring seasons, and was chosen to provide the most stable measure of

9 Supermarket Facts: Industry Overview 1998. Food Management Institute. Press Release, 10/27/1999.

10 Assume lighting use of 2 watts/ft^2. 6,250 hours per year, at $0.8/kWh.

individual store performance over a long period, while maximizing the size of the available sample. The sales index varied from about 2 to 14, and averaged about 5.

The definition of the daylight variable for the retail study was very simple: the skylight design was essentially identical in all the stores with skylights, so we assigned a yes/no skylight variable to each store site. This variable was provided from the retailer's database, and verified with spot site visits.

The retailer was also able to provide us with additional data about each store, which included:

- Square footage of store
- Hours of operation
- Location (zip code)
- Date of original construction
- Date of most recent major renovation
- Historical type of store, which influenced basic construction materials and architectural design.

The store zip code location was used to add census information about population size and average household income. This is a less then perfect description of potential shopping population since a store might serve other neighboring zip codes with different demographics.

Other information was not available to us, but could have refined the precision of the analysis to include population density, number of competitors within a given distance, traffic patterns, and other such measures of real estate value of a retail site.

SIGNIFICANT VARIABLES:	B	Std. Error	t	Sig.	Order of Entry	Change in R^2
(Model Constant)	2.47	1.52	1.63	0.106		
Skylights	**1.55**	**0.36**	**4.35**	**0.000**	**5**	**0.04**
Hours open per week	0.02	0.01	2.65	0.009	1	0.16
Population (per 10,000)	-0.16	0.08	-1.99	0.049	9	0.02
Average income ($10,000s)	-0.20	0.10	-2.03	0.045	8	0.01
Years since last retrofit	-0.32	0.06	-5.12	0.000	3	0.09
Outlier 97	6.91	1.41	4.90	0.000	2	0.12
Outlier 57	4.98	1.44	3.47	0.001	7	0.05
Outlier 94	4.23	1.43	2.97	0.004	4	0.05
Outlier 15	5.82	1.57	3.70	0.000	6	0.04
					Model R^2	**0.58**
NON SIGNIFICANT VARIABLES:	Store types Gross square feet Years since original opening					

Figure 1—Retailer regression findings

Findings

Of the data available to us, it was determined there were five main variables that had a significant effect on the gross sales per store. These variables were: the presence of skylighting, the number of hours the store is open per week, the population and income of the store's zip code and the number of years since the store has last been remodeled.

Other variables that dropped out as not significant included size of store, year of opening and type of store. We tested for non-linear relationships between gross square feet and gross sales and found none. Basically, the chain had settled on an ideal size for a store, and avoided much variation from that preferred size. Thus, size of the store in our sample was not a reliable predictor of sales.

Figure 1 presents the results of the regression equation in tabular form. The B variable is a measure of the magnitude of the impact of each significant variable relative to the sales index. The skylight B coefficient of 1.55 indicates that a store with skylights is predicted to have a sales index 1.55 points above the chain norm, all other conditions being equal.

Standard Error and the T-statistic are measures of the spread of the data. The significance is the probability that this finding could have a null effect, or not be reliable. In order to be included in the model, variables had to have a maximum of 10 percent probability of a null effect (or conversely, a minimum of 90 percent certainty of a true effect). The order of entry describes the power of the variable in predicting the sales index for a store. The change in R^2 describes the amount of variation in the data that is explained by the variable. The model R^2 of 0.58 means that 58 percent of the variation in the data is explained by the variables included in the model. Of the 108 stores studied, four were identified to be "outliers," or so exceptional that they were excluded from influencing the findings.

The table shows that the skylighting variable has the largest positive effect on sales of all variables considered. In addition, there is a 99.9 percent certainty that this is a true effect associated with skylighting. It is the third most powerful variable considered (excluding the outliers) in predicting store sales performance.

Interpreting the retailer results

In this analysis, we were not able to describe the absolute dollar value of the skylighting variable, therefore we will try to describe the relative effect of the presence of skylighting on sales in other ways.

These results show that adding skylighting to the average non-skylit store within this chain would be likely to improve its performance by 40 percent, with a probable range somewhere between 31 and 49 percent. For example, applying the grocery store national average example discussed earlier, if this non-skylit store were averaging sales of $\$500/ft^2$ per year, then its gross sales might be expected to increase to between \$655 and $\$745/ft^2$ per year with the addition of a skylighting system.

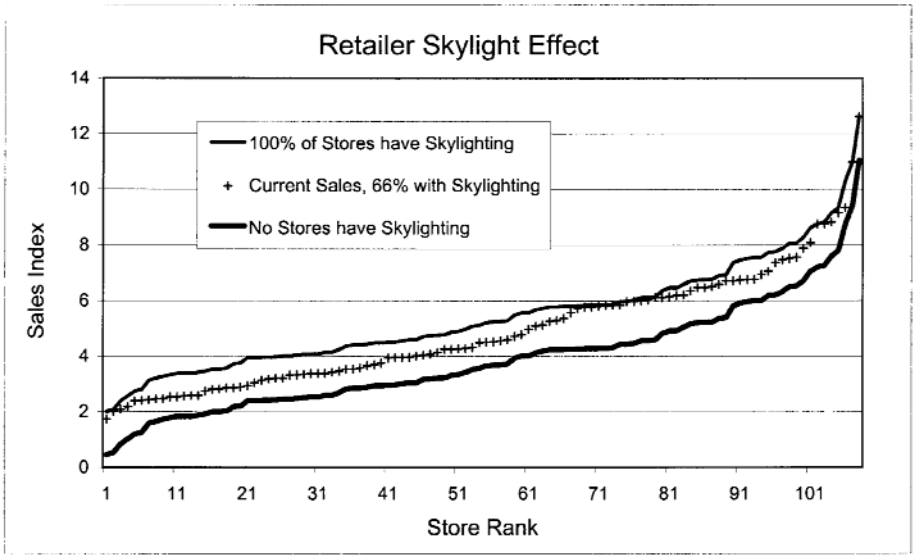

Figure 2—Chain-wide sales index with and without skylighting.

An alternative way to think about the impact of the skylighting is to ask how skylighting affects the overall gross sales for the chain as a whole. Currently 66 percent of the chain's stores have skylighting. If the chain added skylights to the rest of its locations, what effect would that have on gross sales? **Figure 2** shows both the effect of adding skylighting to all stores in the chain, and the effect of removing the skylighting from all stores. The difference is dramatic. If this particular chain were to add skylighting to the remaining 34 percent of its stores, chain-wide sales could increase by up to 11 percent. The difference between no skylighting in *any* of the stores, and skylighting in *all* of the stores, is a likely 40 percent increase in chain-wide gross sales.

Another way to interpret the results is to compare the relative effect of other variables. For example, adding skylights to a store in this case has about the same magnitude of an effect as remodeling the store every five years (1.55/.32) or of operating the store an additional 78 hours per week (1.55/.02).

Limitations of the study

It should be remembered that there were many other variables not considered in our analysis, such as the number of competitors within a store's territory. Also, in spite of the apparent uniformity of the stores, there may be operational differences between skylit and non-skylit stores that were not visible to the observer. For example, the air temperatures might be slightly different, or they may tend to use different music play lists that somehow affect sales. If such additional variables could be properly identified and found significant in the analysis, then magnitude of the skylighting effect would most likely be reduced. Thus, the 40 percent effect should be considered an upper bound of a likely effect for this chain.

There is also no way to know how these results would translate to another retail chain. A different chain would have a different distribution of sales per store, which would change the percentage effect. It is, of course, also unknown how skylighting of a different design would affect a store with different operations. The results of the regression equation are specific only for this data set. However, while magnitudes may vary in other analyses, we can say that in this case there clearly seems to be a strong positive effect to skylighting, and it is quite significant.

Our data set did not allow us to investigate other relationships between daylighting and sales, such as whether sales might increase during the daytime for skylit stores, or whether the variation in illumination levels associated with daylight was correlated to a change in sales.

Possible mechanisms

This kind of statistical analysis cannot prove skylighting causes increased sales. It can only demonstrate that there is a strong correlation between the presence of skylighting and increased sales. The reason for the effect is left to hypothesis at this point.

Many possible mechanisms for daylighting effects on human behavior have been suggested. For this retail case, these can generally be summarized as improved vision, improved morale, and increased customer loyalty. The increased sales associated with the daylit stores might be a function of any one, or any combination of the following:

- Improved vision due to:
  - Higher illumination levels under daylight
  - Better color rendition under daylight
  - Improved spectral content of daylight (scotopic enhancement)
  - Improved three-dimensional modeling with high lights and shadows
  - Reduction of flicker effects from electric lighting
- Improved shopper and/or employee morale due to:
  - Mental stimulation from varying lighting conditions
  - Calming effect of a connection with the natural world (weather, time of day)
  - Biochemical responses to daylight resulting in greater mental alertness (neurotransmitter levels)

- Improved shopper and/or employee loyalty due to any combination of the above.

All of these potential mechanisms are under investigation by other researchers. It will certainly require a coordinated strategy using a combination of methodologies—laboratory experimentation, field work and population studies—to clearly delineate a mechanism. Further studies will hopefully be able to quantify effects from other, more precisely defined, aspects of the luminous environment, and eventually create linkages to mental, emotional or biochemical processes.

Shopper interviews

Interviews with shoppers were not a formal part of this study, but provide some insight into possible mechanisms of skylighting on sales.

Informal interviews with shoppers repeatedly confirmed that the vast majority of shoppers were not aware of the skylights. The questioner, looking just like any other shopper, would approach a shopper and ask: "May I ask you a question?" The response was universally affirmative. We then asked, "What do you think of the skylights in this store?" The typical response was to look up, look puzzled, and then say, "That's funny, I never noticed them before." Out of 42 interviews in 10 skylit stores, only three shoppers could be found who were already aware of the skylights. Two of those volunteered that they had only noticed the skylights because their small child had pointed them out on an earlier trip, while looking up at a balloon.

The questioner then asked: "Does this store feel any different to you than other stores like this?" By far the most common response (80 percent) was, "This store feels cleaner." The second most common response (65 percent) was, "It feels more spacious, more open." About one third of the respondents also mentioned it was brighter. Three middle-aged respondents volunteered that they specifically came to this store instead of another closer to their home because they liked how it felt—cleaner, more open. Three elderly respondents commented on how important the brightness and the light quality were for them (although none had been aware of the skylights). Two middle-aged respondents talked about how important "natural" light was. Two older men commented that the energy savings must be considerable. Not one respondent objected to the skylights or had any negative comments about them.

Five store managers were interviewed about the skylights. All were positive about them, and reported they thought their customers liked them. Two mentioned the importance of energy savings. One commented on the "inviting feeling" the skylights created. Five store clerks were also interviewed: three were generally indifferent to the skylights; two were very positive, one saying, "I love them!"

Conclusion

By performing statistical analysis on a large population of similar buildings we were able to isolate probable effects of daylighting on human behavior, as evidenced in sales data for a retail chain. This study provides a useful gauge of the potential magnitude of such effects and the probability that these effects are a valid finding.

The findings in this particular analysis, of a 40 percent increase in sales for those stores with skylights within one chain of stores, should be taken as an upper bound of a possible effect. The magnitude of the effect is expected to be largely a function of the particular chain, its sales profile and its store design. The positive effects of skylighting on sales, and the strength of the association, are the most certain results of this study.

The studies do not, however, offer any explanation of why such an effect would occur. Nor do they prove a causal relationship: it remains unknown if it is indeed the daylight, or some other associated condition, which is causing the observed effects. Informal interviews have suggested that while customers are definitely not aware of the presence of skylights, both they and employees do have very positive perceptions of the skylit stores in general.